# UAS Integration in the NAS: Detect and Avoid


Conrad Rorie *for*

Jay Shively

**Detect and Avoid**

**Sub-Project Manager**

# UAS-NAS Phase 2
# Project Organization Structure

PROJECT OFFICE LEVEL

**Project Leadership**

| | |
|---|---|
| Project Manager (PM) | Robert Sakahara, AFRC |
| Deputy PM | Davis Hackenberg, AFRC |
| Chief Engineer (CE) | William Johnson, LaRC |

**Project Support**

| | |
|---|---|
| Sr. Advisor | Chuck Johnsons, AFRC |
| Staff Engineer | Dan Roth, AFRC |
| Lead Resource Analyst | April Jungers, AFRC |
| Resource Analysts | Amber Gregory, AFRC<br>Warcquel Frieson, ARC<br>Julie Blackett, GRC<br>Pat O'Neal, LaRC |
| Scheduler | Irma Ruiz, AFRC |
| Risk Manager/Outreach | Jamie Turner, AFRC |
| Change/Doc. Mgmt | Lexie Brown, AFRC |
| Admin Support | Sarah Strahan, AFRC |

**Project Systems Engineering Office**

| | |
|---|---|
| Deputy Chief Engineer | Clint St. John, AFRC |
| SIO Technical Manager | Kurt Swieringa, LaRC |

SUBPROJECT LEVEL

**Command and Control (C2)**

Subproject Manager

Mike Jarrell, GRC

Subproject Technical Lead

Jim Griner, GRC

**Detect and Avoid (DAA)**

Subproject Manager

Jay Shively, ARC

Subproject Technical Lead

Gilbert Wu (A)/Confesor Santiago, ARC; Lisa Fern; ARC; Tod Lewis, LaRC

**Integrated Test and Evaluation (IT&E)**

Subproject Manager

Mauricio Rivas, AFRC / Jim Murphy, ARC

Subproject Technical Lead

Ty Hoang, ARC (A) ; Sam Kim, AFRC

(A) Acting

# UAS-NAS Project Value Proposition

## NASA UAS-NAS Project Activities

### TC C2 — C2 Performance Standards

- Research C2 SatCom Systems
- Develop C2 Prototype Terrestrial System
- → Conduct C2 Flight Test and MS&A
  *Data Link, CNPC Spectrum, CNPC Security, BVLOS/BRLOS, ATC Interoperability*
- → Develop C2 Requirements

### TC DAA — DAA Performance Standards

- Develop DAA Test beds
- → Conduct DAA Flight Test and MS&A
  *Human Factors Performance Trade-offs, Low Cost SWaP sensors, Well Clear, Collision Avoidance*
- → Develop DAA Performance & Interoperability Requirements

### Integrated Test & Evaluation

- Develop DAA Prototype System
- → Live Virtual Constructive (LVC) Test Infrastructure
- → Conduct Technology and CONOPS testing
  - ACAS Xu FT2
  - No Chase COA
  - Conduct FT5 Test Scenarios
  - Conduct FT6 Test Scenarios

### SIO — Systems Integration and Operationalization

- Develop Robust NASA/ Industry Partnership
- → Develop certification compliance toolkit(s)
- Integrate Essential Technologies
- → Conduct Demo

## Key Products

**C2 Performance Requirements to inform C2 MOPS** → RTCA Terrestrial MOPS → C2 Technical Standard Order (TSO)

**DAA Performance Requirements to inform DAA MOPS** → RTCA Non-Coop Sensor MOPS

**Re-usable Test Infrastructure** → RTCA GBDAA MOPS; RTCA DAA MOPS Rev A/B

RTCA GBDAA MOPS → DAA Technical Standard Order (TSO)

**Substantiated path** → Generic Certification Compliance Toolkit(s)

## Resultant Outcomes

C2 Technical Standard Order (TSO)

DAA Technical Standard Order (TSO)

Generic Certification Compliance Toolkit(s)

# DAA Subproject Structure for Project Phase 2

TECHNICAL CHALLENGE/ SUBPROJECT LEVEL

**Detect and Avoid**

**<TC-DAA>**

**Subproject Manager (SPM)**

*Jay Shively, ARC*

**Subproject Technical Leads**

*Gilbert Wu (A), ARC; Lisa Fern; ARC; Tod Lewis, LaRC*

TECHNICAL WORK PACKAGE LEVEL

- **Alternate Surveillance Requirements**
- **Well Clear Alerting Requirements**
- **ACAS Xu**
- **External Collaborations**
- **Integrated Events**

SCHEDULE PACKAGE LEVEL

*DAA Performance Standards*

**Develop DAA Test beds**

**Conduct DAA Flight Test and MS&A**

*Human Factors*
*Performance Trade-offs*
*Interoperability*
*Self Separation*
*CONOPs*
*Well Clear*
*Collision Avoidance*

**Develop DAA Performance & Interoperability Requirements**

*DAA Performance Requirements to inform DAA MOPS*

RTCA Non-Coop Sensor MOPS

RTCA DAA MOPS Rev A/B

GBDAA MOPS

**DAA Technical Standard Order (TSO)**

# See and Avoid: FAR Sec. 91.113

- General. When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft. When a rule of this section gives another aircraft the right-of-way, the pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless well clear.

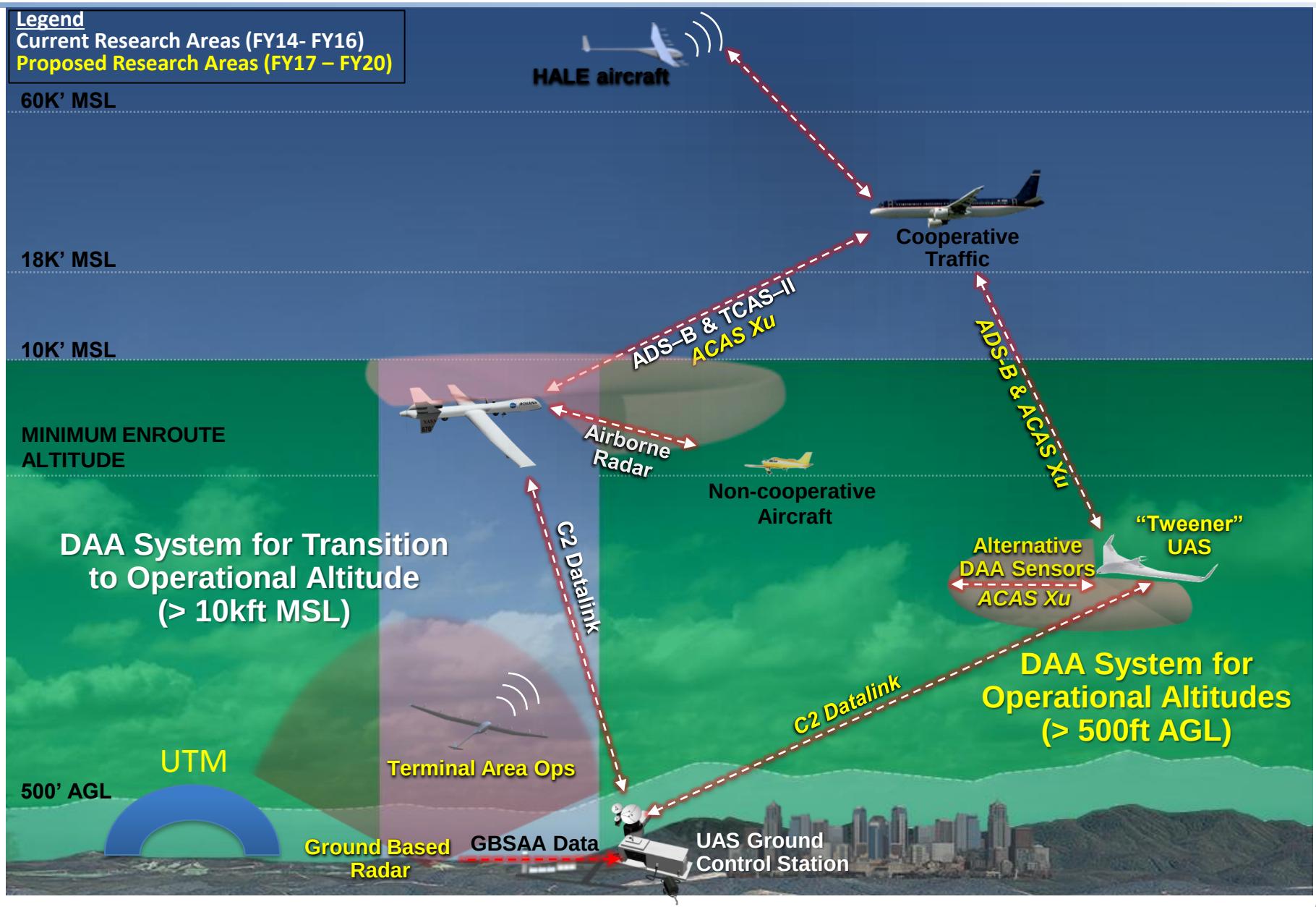
- Piloted “see and avoid” => UAS “detect and avoid”

- Pilot vision => surveillance sensors (on- or off- board, or both)

- Pilot judgment of well clear => mathematical expression of well clear

- Phase 1 DAA well clear defined as:
- Horz Miss Distance = 4000ft
- Vert Miss Distance = 450ft
- modTau = 35sec
- DMOD = 4000ft

# DAA Operational Environments



# Phase 1 Accomplishments

- RTCA DO-365:
  - Minimum Operating Performance Standards for Detect and Avoid Systems
- RTCA DO-366:
  - Minimum Operating Performance Standards for Air-to Air Radar Traffic Surveillance

- FAA Technical Standard Orders:
  - TSO-C211, Detect and Avoid
  - TSO-C212, ATAR for Traffic Surveillance

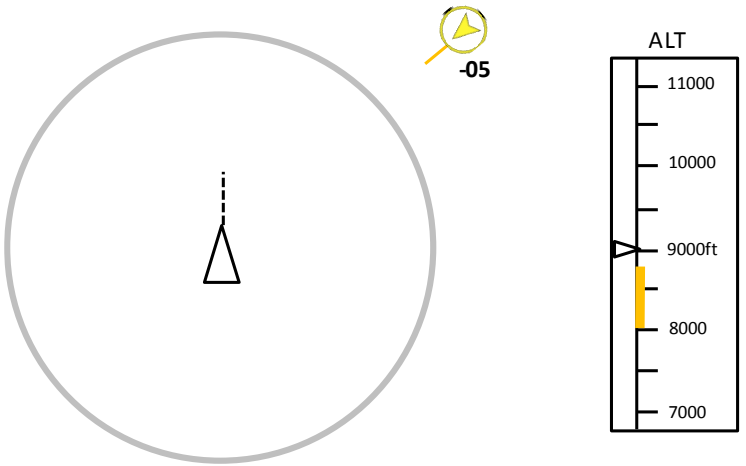
- NASA DAA Team Contributions:
  - Well clear definition
  - Alerting
  - Guidance
  - Displays
  - Reference algorithm
  - Extensive modeling and simulation

# Phase 1 DAA Alerting

| Symbol | Name | Pilot Action | DAA Well Clear Criteria | Time to Loss of DAA Well Clear | Aural Alert Verbiage |
|---|---|---|---|---|---|
|  | Warning Alert | • Notify ATC as soon as practicable after taking action | DMOD = 0.66 nmi<br>HMD = 0.66 nmi<br>ZTHR = 450 ft<br>modTau = 35 sec | 25 sec | “Traffic, Maneuver Now” x2 |
|  | Corrective Alert | • Coordinate with ATC to determine an appropriate maneuver | DMOD = 0.66 nmi<br>HMD = 0.66 nmi<br>ZTHR = 450 ft<br>modTau = 35 sec | 55 sec | “Traffic, Avoid” |
|  | Preventive Alert | • On current course, corrective action should not be required | DMOD = 0.66 nmi<br>HMD = 0.66 nmi<br>ZTHR = 700 ft<br>modTau = 35 sec | 55 sec | “Traffic, Monitor” |
|  | Guidance Traffic | • Traffic generating guidance bands outside of current course | Associated w/ bands outside current course | X | N/A |
|  | Remaining Traffic | • Traffic within sensor range | Within surveillance field of regard | X | N/A |

# Phase 1 DAA Suggestive Maneuver Guidance

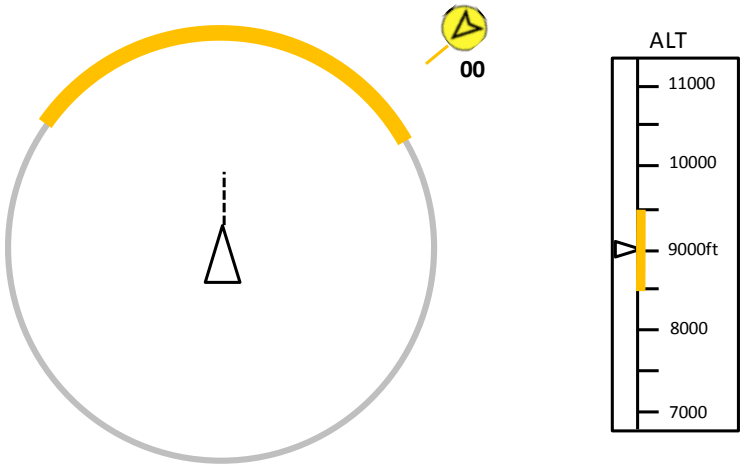
## Remain DAA Well Clear Corrective Guidance




Inner Range Ring

Altitude Tape

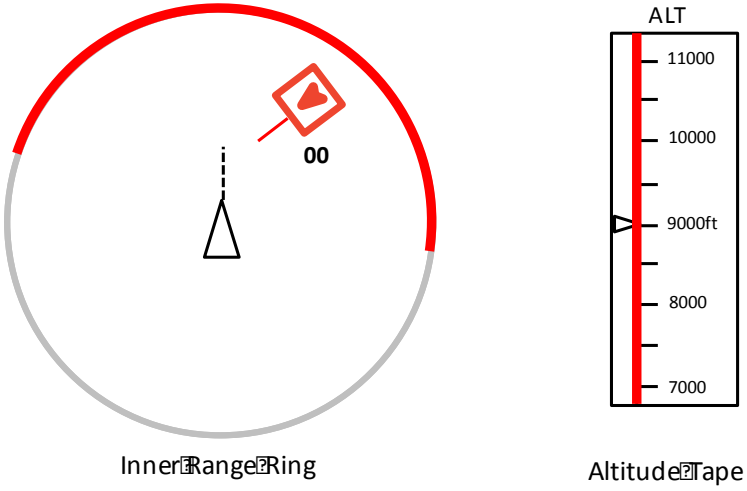
## Remain DAA Well Clear Corrective Guidance




Inner Range Ring

Altitude Tape

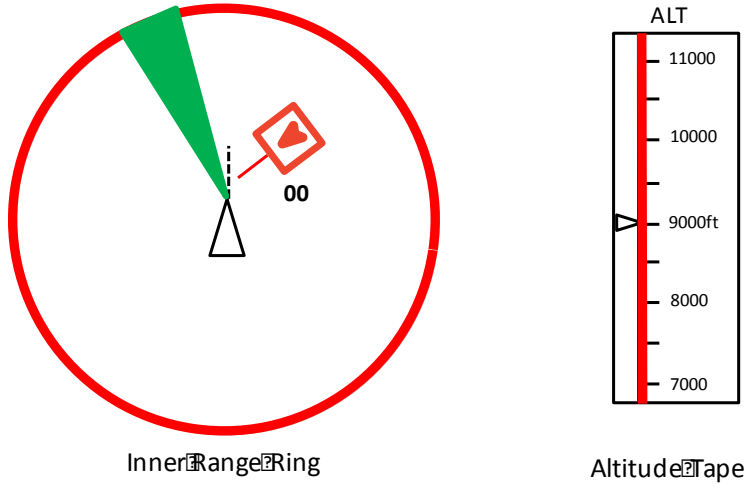
## Remain DAA Well Clear Warning Guidance




Inner Range Ring

Altitude Tape

## Regain DAA Well Clear Guidance

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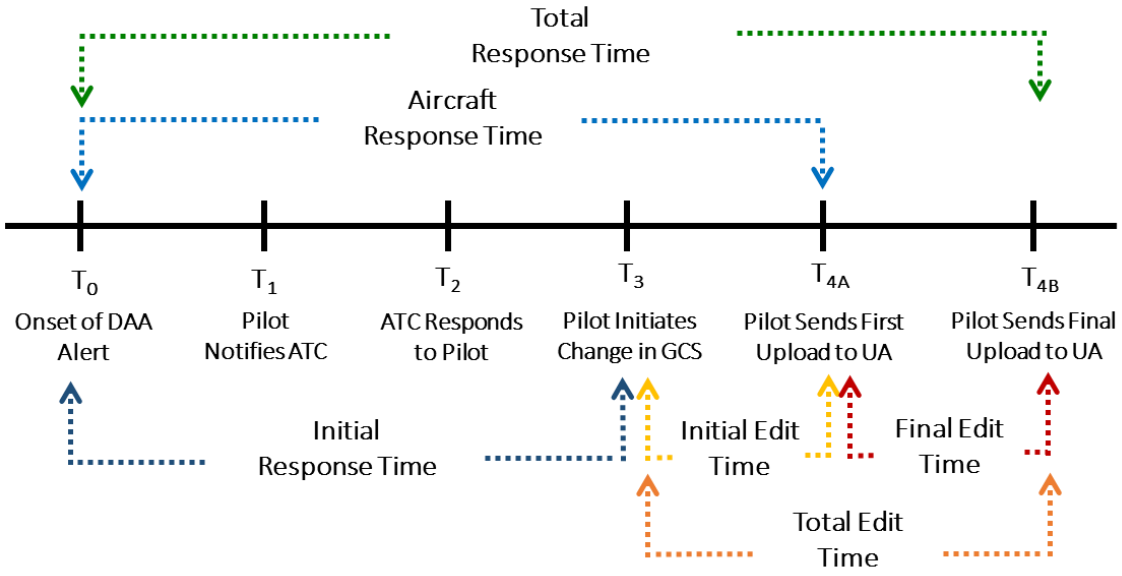
# HSI DAA Performance Metrics

- Multiple human-in-the-loop (HITL) simulations were performed to identify requirements for UAS DAA systems. The following metrics were used to assess pilot and system performance:
  - Pilot response times
  - Proportion of losses of DAA well clear
  - Severity of losses of DAA well clear
  - ATC interoperability
  - Subjective assessment & workload

Pilot-Air Traffic Control Interaction Timeline & Metrics



# Plans for Phase 2 (FY 18 – 20)

- Augmented Well Clear Definitions
  - Terminal
    - 2 HITLs (TOPS 1/1B) **completed**, 3rd HITL (TOPS 2) in planning at LaRC
  - Low SWaP
    - HITL planned for NOV 2018
- ACAS Xu
  - Horizontal RAs
  - Auto-Execute & Return-to-Course functionality
- Low SwaP Sensors
  - RADAR
    - Cooperative agreement with Honeywell
- Flight Tests
  - FY 19 – Low SWaP RADAR
    - Unmitigated encounters
  - FY 20 – Pilot response to new well clear definition; use of Low SWaP RADAR